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SPECIALISTS IN SATELLITE, MEDIA AND TELECOM INVESTMENT BANKING

A Look Inside…

Broadband Wireless Access: An Industry Primer

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Key Takeaways:

1. Technologies vary widely for wireless broadband including not only the spectrum used but also the different transmission techniques and industry standards utilized by operators.

2. The FCC regulates all of the broadband wireless spectrum in the US and has divided it up into licensed and unlicensed (typically low-powered) bands.

3. Cable, DSL, BPL, and Satellite services will all be competing with each other to gain subscribers in the upcoming years.

4. Within the broadband wireless ecosystem, there are hardware providers manufacturing chipsets, base stations, antennas, etc. and service providers.

5. Demand for broadband wireless services will increase, fueled by the increasing demand for internet services and data centric media such as video.

ABOUT NEAR EARTH LLC

Near Earth is a specialized Investment Bank which brings the highest quality senior level attention to companies in the greater commercial satellite/space, telecom, media, entertainment, and technology industries.

Near Earth provides a full range of capital raising, advisory and consulting services to companies and their Boards. We also provide financial advisory services, valuation, structuring, and due diligence support to private equity, hedge and distressed debt funds. Please contact us if you would like our assistance with a contemplated satellite, telecom or media investment or portfolio divestment.

tourbillon international
Publisher of
WATCHES GRAND COMPLICATIONS
has been acquired by
MODERN LUXURY
MAGAZINES
Near Earth LLC acted as exclusive financial advisor to Tourbillon International
GE Commercial Finance
Valuation of Five Satellite Related Assets of SES Global
SES
Near Earth LLC provided in-depth asset valuation and industry analysis
LINKSTORM
Series C Convertible Participating Preferred Stock
The Near Earth Investment Club financed a portion of the round
Undisclosed Major Asset Management Firm
Valuation and Strategic Analysis of Loral Space & Communications
LORAL
Space & Communications
Near Earth LLC completed in-depth analysis
uplinkearth
Luxmovera LLC
d/b/a uplinkearth
Financial and Business Analysis, Planning and Valuation
Near Earth LLC acted as financial advisor to Luxmovera LLC
MCM
Murray Capital Management
Valuation of three telecom portfolio holdings
Near Earth LLC provided in-depth valuation and industry analysis
HUGHES
Hughes Network Systems
Valuation of spectrum related assets
Near Earth LLC provided in-depth valuation and analysis
Intelsat.
Intelsat. Ltd.
Private sale of minority block of shares
Near Earth LLC acted as advisor to investor group
$110,000,000
Pacific Corporate Group LLC
served as the lead investor in
ORBCOMM
Series B Redeemable Convertible Preferred Stock
Near Earth LLC acted as Financial Advisor to PCG
$5,400,000
HorseTV
Series A Convertible Preferred Stock
The Near Earth Investment Club financed a portion of the round
SES AMERICOM
SES AMERICOM
Valuation of orbital slot
Near Earth LLC valued assets for expert witness testimony
INTERNATIONAL DATACASTING
International Datacasting, Corp.
Acquisition of PROFline B.V.
Near Earth LLC acted as strategic advisor to the acquirer
XM Satellite Radio, Inc.
Creation of Canadian joint venture
Near Earth LLC acted as financial advisor to both parties
XM Satellite Radio, Inc.
$435 million private placement
Near Earth LLC acted as financial advisor to the issuer

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Executive Summary

Driven by increasing demand for broadband access to the internet backbone, a wide array of technologies are being developed to address the associated business opportunity. One of the fastest growing of these technologies is delivery for wireless broadband service, both to fixed and increasingly mobile users. As detailed in this paper, there are numerous competing technologies as well, including cable modems, satellite (really a subset of wireless delivery), Broadband over Power Lines (BPL) and DSL.

This growth is being driven by invention and application of a wide array of technologies, each of which has its own advantages, disadvantages and quirks. Some of these include variation by power and frequency (often driven by the regulatory regimes in the specific countries involved), modulation scheme or network topology. We discuss each of these and their relative capabilities in detail in this paper. At this early stage of adoption, it remains far from certain which of these approaches will be more successful, but in Near Earth's view it is likely that business execution will prove at least as important as technological differentiation.

Similarly, a large number of entrants are competing with in-house efforts at the "usual suspects" telecommunication firms such as Motorola, Nokia and others. These new entrants typically have focused product/service lines, and due to their lack of scale we expect most of these new entrants to disappear either through competition, or in many cases consolidation with each other and the industry giants.

Due to strong scale advantages, we expect a limited number of "pure play" surviving companies and technologies to emerge, with strong pricing benefits that will accrue to service operators and their customers. We believe that the emerging giants (and the companies that either become one or join forces with one) and service operators will be the chief financial beneficiaries of these new technologies. Within geographic and regulatory niches (such as those created by licensed spectrum) we also expect long term success from smaller operators, as well.

Introduction

Here at Near Earth Capital, we work across the industry of digital communications. As the world migrates to an increasingly unwired, but still very much connected state, we have observed the emergence of new technologies, business models and industry participants seeking to capitalize on the opportunity this presents.

In this review, we attempt to catalog the varying approaches, competing technologies and companies that together comprise this vibrant and rapidly growing space.

Broadband Wireless service can be provided by frequencies as low as 700 MHz to over 80 GHz

Technology Overview

Frequencies

Broadband Wireless service can be provided by a wide range of frequencies, ranging from frequencies as low as 700 MHz to over 80 GHz (or 80,000 MHz, if you prefer) – not counting the even higher infrared frequencies (commonly referred to as free space optics, or FSO for short). The physics of these various frequencies affect both the technology (and thus the cost) of how they are produced as well as their propagation characteristics. While it is well beyond the scope of this paper to fully explore this topic, we do intend to summarize some of the important issues concerning frequency that affect deployment, reliability and ultimately the business models.

LOS deployment is the most challenging from a business perspective. model.

Here we discuss the engineering and physics that using various frequencies imposes – later, we also discuss the regulatory issues that affect the frequency choices operators face when deploying Broadband Wireless.

Propagation and Range

For broadband wireless access, range is a strong function of the type of deployment:

Line Of Sight (LOS) deployment is the least challenging from an engineering perspective, but the most challenging from a business perspective. In this type of deployment, a direct unobstructed (or nearly so) line of sight is required from each user to a base station. In practice, this means that many users who order service will be unable to receive it, or they may require locating antennas on tall masts or other structures to ensure the clear line of sight. This is often expensive or unacceptable to the customer.

The most challenging deployment from an engineering perspective is indoor NLOS

The next most challenging (again from an engineering perspective) type of deployment is outdoor Non Line Of Sight (NLOS) deployment. In this case, higher power signals (combined with shorter transmission distances) are used to bounce signals around and through obstacles. In these cases the reception antenna at each user can be placed wherever convenient outside the user's building.

Finally, the most challenging deployment from an engineering perspective is indoor NLOS. Once the receiving antenna is inside, it can be placed on a desktop or wherever the users finds it convenient, turned on and the unit starts working. This allows users to self install their systems, at a very considerable

cost savings to the service operator. These savings come at the expense of much shorter range, which in turn requires many more base stations. Typically, data rates for this type of deployment are slower than for the prior two types as well.

…lower frequencies are better at penetrating obstacles and diffracting (going around corners).

All other factors being equal, lower frequencies are better at penetrating obstacles and diffracting (going around corners). In broadband wireless deployments, these obstacles commonly include building structures, foliage and even raindrops, among others. To an extent, and as permitted by the regulatory environment, it can be possible to use extra transmission power to overcome these obstacles as well. Alternatively, operators can deploy extra transmitters to help ensure that users are close enough to towers. This represents a tradeoff between extra equipment capital expenditure and choice of spectrum.

…current technology limits non line of sight deployments to ~2.5 GHz and below.

From a practical basis, current technology limits non line of sight deployments to ~2.5 GHz and below (except for very short ranges such as WiFi). Non line of sight deployments are particularly attractive for developed countries where truck rolls are expensive due to high labor costs. As frequencies continue to rise, in the ~15 GHz and up range, raindrops become a significant and progressively worse source of attenuation, affecting propagation during rain storms depending on the severity of the downpour. Finally, as frequencies pass 60 GHz and continue into the infrared, they begin to become susceptible to fog as well.

Transmission Techniques

Broadband Wireless uses a variety of modulation techniques to transport data. Some of the most common techniques are described in brief here.

Phase Shift Keying

A common technique is to vary the phase of the transmission waveform to convey digital information. The extent this works depends on how strong and clean (i.e. static free) the signal is – stronger and cleaner signals allow greater data rates using the same spectrum. The WiMax standard includes several levels of phase shift keying, notably QPSK (4 bits), 16 QAM (16 bits) and 64 QAM (64 bits). Depending on whether conditions are favorable, the standard allows transmitters to vary the modulation to get as many bits per second to the receiver as possible while assuring that the bits are not corrupted. Phase shift keying is not a proprietary technique and is widely used with other technologies.

There has been rampant speculation that Flarion is likely to unleash an army of lawyers to extract licensing fees from other WiMax equipment vendors.

OFDM

This technique can be combined with Orthogonal Frequency Division Multiplexing (OFDM), where many individual low data rate streams that are spaced at varying frequencies are combined to form a single high data rate stream. The use of this technique helps data transmission under tough conditions (e.g. obstacles, interference, etc.), and is used in WiFi, WiMax and other Broadband Wireless standards. Many OFDM techniques are patented by Qualcomm's Flarion unit, which recently executed a licensing agreement with Soma Networks, a WiMax equipment vendor. There has been rampant speculation in the industry that Flarion is likely to unleash the Qualcomm army of lawyers to extract licensing fees from other WiMax equipment vendors as well.

CDMA

Code Division Multiple Access (CDMA) is a technique where multiple digital streams are all transmitted in the same frequency band simultaneously, and digital codes are used to distinguish the respective streams from each other and the background noise. Qualcomm owns most of the intellectual property related to the practice of CDMA and uses a licensing model for sharing this technology with manufacturers and service providers. W-CDMA is a specialized implementation of CDMA and uses the same underlying principles.

Industry Standards

WiFi

WiFi uses unlicensed spectrum of 2.4 GHz that is broken into 11 channels that can be used simultaneously.

WiFi is a set of international standards, and includes 802.11b and 802.11g standards, which support data rates of up to 11 megabits/second and 54 megabits/second, respectively. An emerging 802.11n standard promises even faster speeds. When signal strength or interference occurs, lower data rates are used to maintain communications, where possible.

WiFi uses unlicensed spectrum of 2.4 GHz that is broken into 11 channels that can be used simultaneously. Because power for unlicensed WiFi equipment is limited by regulation, range is limited – typically to 100 meters or less. Both OFDM and phase shift keying techniques are used.

WiFi equipment is available from a wide variety of vendors who comply with the standard, at very competitive prices due to the maturity of the technology. Because it does not provide for handoffs, WiFi is used for deployments with stationary or nomadic users.

Two of the hallmark techniques of WiMax are varying the transmission waveform and the use of OFDM

WiMax

The WiMax standard is defined by the WiMax Forum, an industry consortium and by the IEEE, where it is referred to as 802.16d/e. (The “d” suffix refers to the fixed standard; the “e” suffix refers to the mobile standard) Two of the hallmark techniques of WiMax are varying the transmission waveform and the use of OFDM – much like WiFi. The WiMax standard can be used at a variety of frequencies, depending on the licensing regime for the deployment. Popular frequencies include the following:

Exhibit 1: Popular Wireless Spectrum Frequencies in the US

Frequency	Amount	Uses
900 mHz	30 mHz	U.S. unlicensed. Superior propagation characteristics due to low frequency.
1.7 and 2.1 GHz	90 mHz	Advanced Wireless Services in US; can be used for WiMax - service rules for this spectrum also permit voice services, making it particularly valuable. Just auctioned for $13.7 billion.
2.3 GHz	60 mHz	Wireless Communications Services in US; expect incumbent service providers who already hold this spectrum to use it for WiMAX services
2.4 – 2.483 GHz	83 mHz	ISM and FCC Part 15, largely unlicensed, used for WiFi; to be avoided by WiMAX operators on concerns of interference from WiFi
2.5 GHz	195 mHz	BRS/EBS in US; - Projected as being a popular licensed WiMAX spectrum choice in US and for those who could not get 3.5 GHz in other nations, probably the second most popular spectrum vendors will build product for. Largely held by Spring and ClearWire.
3.5 GHz	N/A	Unlicensed in many nations outside the US. Many nations have allocated it as the WiMAX spectrum. Almost all vendors offer WiMAX product for this frequency. Not useable commercially in the U.S. (military use).
3.65 GHz	50 mHz	FCC issued an announcement in 2004 promoting opening spectrum here for quasi-unlicensed use. Has yet to be finalized. Many products made for 3.5 GHz may work well in 3.65 GHz U.S. application
4.9 GHz	50 mHz	aka "Public Safety", in the US, intended for use by First Responders (police, fire, ambulance and other emergency services)
5.4 and 5.8 GHz	125 mHz	U.S. unlicensed; many vendors will offer this as their US unlicensed spectrum offering.

Source: FCC and Near Earth Analysis

Data rates for WiMax can reach in excess of 50 megabits per second, and in licensed deployments range can reach 30 miles or more. Unlicensed deployments use much less power, and have much shorter range. For WiMax, range is also a strong function of the type of deployment:

As noted previously, Line of Sight (LOS) deployment is the least challenging from an engineering perspective, but the most challenging from a business perspective. In this type of deployment, the base station and receiver antennas must have an unobstructed line of sight to each other. While this allows for faster data rates, it requires careful installation and qualifying each prospective customer by a site inspection – which significantly increases customer acquisition costs and the potential for future service calls.

An important feature of the WiMax standard is the availability of WiMax Forum certification – which indicates that equipment with this certification is plug compatible with other certified equipment. This allows operators to "mix and

match" equipment from different vendors in their networks. Over time, we expect that this degree of standardization is likely to cause significant pricing pressure in the WiMax industry – to the joy of service operators and chagrin of hardware vendors. We note, however, that due to learning curve effects, early WiMax equipment prices are higher than equipment prices for WiFi, EV-DO and UMTS equipment.

Over time, we expect that this degree of standardization [WiMax standard] is likely to cause significant pricing pressure in the industry

WiMax is considered to be significantly more "spectrally efficient" that the competing EV-DO and UMTS standards due to its use of wider channels. This allows a given amount of spectrum to carry more data – meaning either faster connections or a greater number of users for each unit of spectrum, with obvious cost benefits.

EV-DO

EV-DO stands for EVolution Data Optimized. This is a mobile broadband standard that is an outgrowth of the CDMA technology widely employed by wireless telephone carriers. It supports data rates of up to 3 megabits per second, and equipment is widely available from a variety of vendors at very competitive prices.

WiMax is considered to be more "spectrally efficient" that the competing EV-DO and UMTS standards due to its use of wider channels.

UMTS

UMTS is functionally similar to EV-DO, but is an outgrowth of the GSM standard instead. It has a functional data rate of 1-2 megabits in current deployments, and a theoretical limit of 11 megabits per second. Like EV-DO, UMTS equipment is widely available. Deployments are widespread in Japan, Europe and Africa.

Typical Wireless Broadband Deployment Topologies

Fixed broadband

The first large scale broadband wireless deployments (notably by Sprint, amongst others) in the 1990s provided service to a fixed location, typically a home or business. This was principally because the transmission links required a direct (or nearly so) line of sight between the transmitter and the receiving tower, and also due to the size and power requirements of the receiving equipment. The need for direct line of sight increased customer acquisition costs and service calls (i.e. truck rolls) and ultimately made the business case unsustainable except for higher cost business users.

The receiving tower is then connected to the internet backbone through a leased T-1, fiber or another wireless link. This process of interconnection is called "backhaul".

More recent deployments have been upgraded in two fashions: the first is the use of non line of sight technology (NLOS), which significantly lowers the costs for system operators by allowing users to self-install their equipment. In turn, this eliminates the expenses from truck rolls. Typically, data rates for NLOS deployments are much slower than for otherwise similar line of sight systems. Typically, NLOS also required greater power, which in turn mandates the use of licensed spectrum.

Under "nomadic" deployments, the users are fixed during access to the network, but may move about the coverage area and "light up" at varying locations.

The second type of upgrade coming into use is "nomadic" deployments. Under this topology, the users are fixed during access to the network, but may move

about the coverage area and "light up" at varying locations. An example of this type of use is laptop users setting up shop in a café or office.

WiFi Mesh

In its [WiFi Mesh] deployments, Earthlink has found that a density of 30-40 nodes per square mile provides adequate performance.

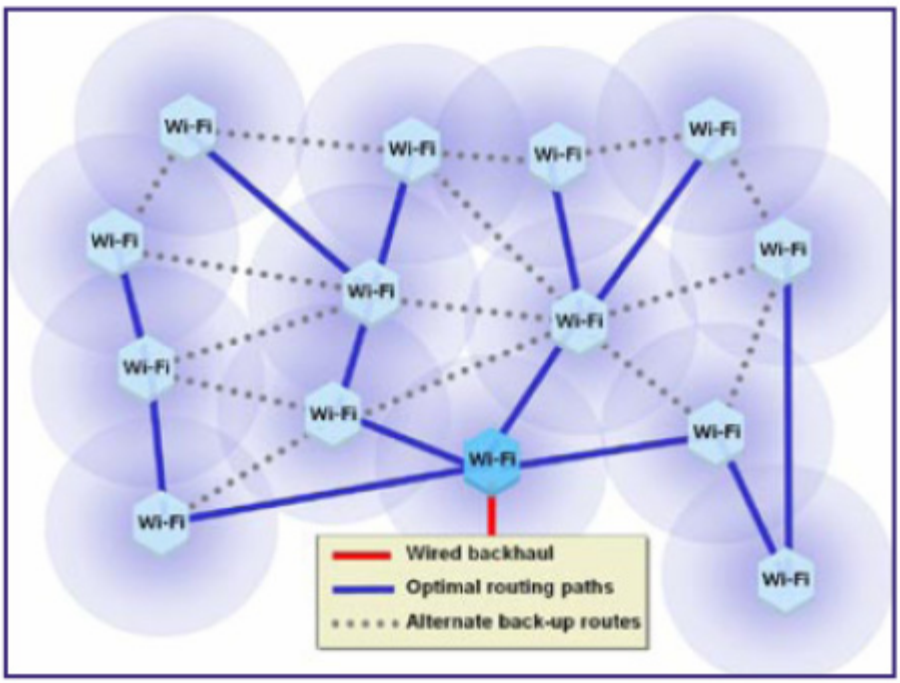
WiFi Mesh networks are a form of the fixed nomadic deployments mentioned in the prior section. There are, however, 2 main differences: The first is that WiFi mesh networks often involve a large number of transmitters due to the relatively short range of the 802.11 standard. This can range from dozens of transmitters to cover a few city blocks to thousands of transmitters blanketing an entire city. (In its deployments, Earthlink has found that a density of 30-40 nodes per square mile provides adequate performance.) A typical node (installed on a streetlamp) is shown in the figure below:

Exhibit 2: A WiFi Mesh Node

Source: MetroFi

The second is that the interconnections between the antenna receiving the users' data and the internet backbone (collectively, "backhaul") are carried over a series of hops from one transmitter of the network to the next until they reach a node that has access to the backbone. Because transmitters are typically within range of multiple other transmitters, this backhaul can take one or more pathways through the network of transmitters, which collectively are referred to as a "mesh." This topology is shown in the figure below:

Exhibit 3: WiFi Mesh Network Topography



Source: Tropos Networks

While the network may have geographic coverage of a large area, no provision is made to allow a user to migrate from one transmitter to another in the network without reestablishing authorization from the network. Thus, if a user loses their connection with a transmitter (if they move outside range of that transmitter, for example), their service is interrupted.

"Cellular"

"Cellular" topologies involve either mesh or non-mesh networks with multiple zones of coverage. In these networks, provision is made to allow a seamless (or nearly so) transition from using one transmitter to another as a user moves. This is directly analogous to the process used in PCS and cellular voice networks. EV-DO and UMTS networks are typically deployed as adjuncts to existing voice networks, and mobile WiMax networks are also expected to use this network architecture.

Regulatory Overview

Licensed Spectrum

[Spectrum] licensing can include not only technical features such as power, modulation, frequency, etc. but also limitations on usage

In the United States, licensing is regulated by the Federal Communications Commission. Licensing for the bands can include not only technical features such as power, modulation, frequency, etc. but can also include limitations on usage – such a whether voice communications can be allowed. Depending on the frequency band, licenses can be freely traded, or alternatively they can be leased to third parties in some instances. In a few cases they are non transferable.

Outside the United States, various licensing bodies prevail in respective countries – though the World Radio Conference provides an international means of coordinating licensing efforts. This coordination effort is important because the production volumes of equipment have strong effects on pricing. To the extent that a particular country adopts an "odd" licensing scheme, it is likely to impose higher costs on operators and consumers in that country.

From the perspective of broadband wireless operators, licenses are often quoted in price per MHz-pop – for example $0.25 for each MHz of spectrum multiplied by the population within the geographic limits of the license. Prices for spectrum rise and fall with the varying fortunes of the industry, but have generally speaking been rising for the last several years. Some typical market prices for U.S. licenses are summarized in the following figure:

Exhibit 4: Prices of Various Wireless Spectrum Bands

Band	Price MHz-POP		Source
WCS	$	0.13	Auction to Nextwave in 2006
WiMax Blend	$	0.14	Nextwave Market Comp (Includes Int. Holdings)
WiMax Blend	$	0.15	Clearwire Market Comp (Includes Int. Holdings)
2.5 GHz	$	0.18	AT&T sale to Clearwire 2007
AWS	$	0.54	Auction in 2006
PCS	$	1.58	Cablevision sale to Verizon in 2003
PCS	$	2.85	Nextwave Sale to Verizon 2004

Source: Near Earth LLC analysis

The Cantor Tower and Spectrum Exchange is a web based marketplace for spectrum and tower assets that facilitates transactions in this area.

Unlicensed Spectrum

In the United States, the unlicensed bands are at 900 MHz, 5.4 GHz and 5.8 GHz.

Unlicensed Spectrum is available in a variety of bands in the various jurisdictions. In the United States, the unlicensed bands are at 900 MHz, 5.4 GHz and 5.8 GHz. Throughout much of the rest of the world, the 3.5 GHz band is also unlicensed.

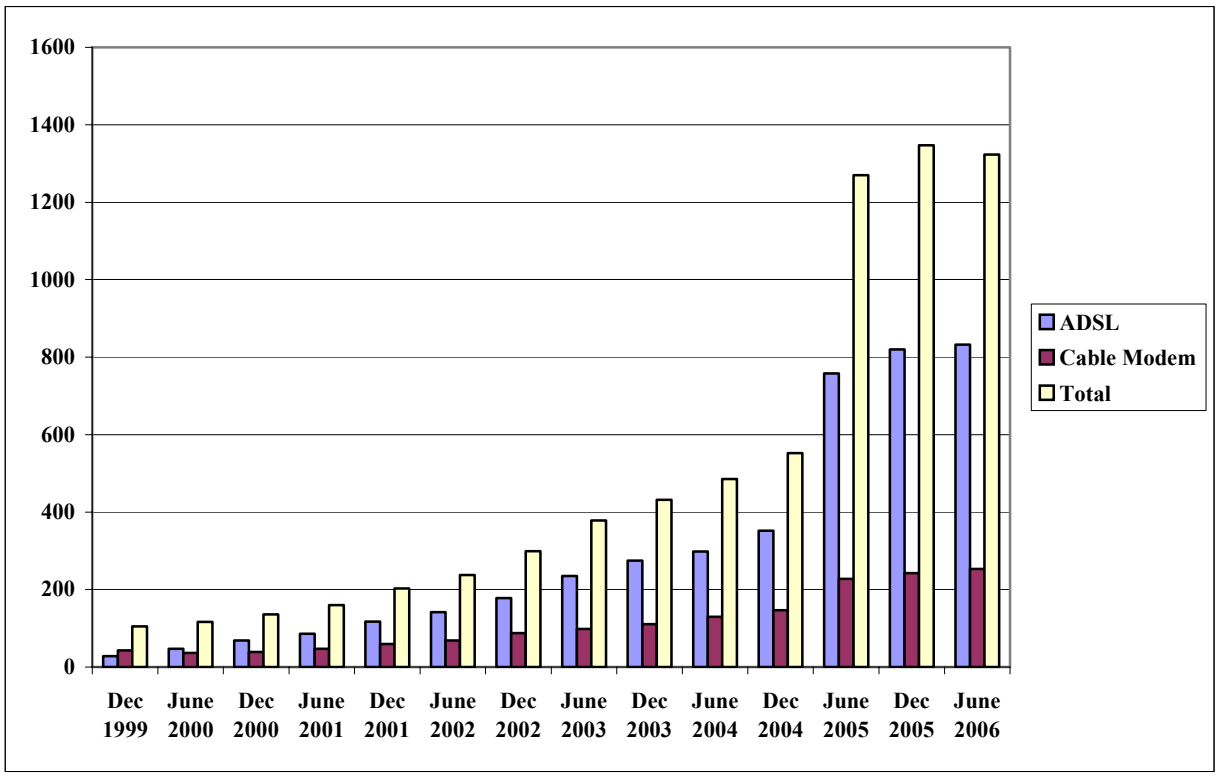
Unlicensed is not unregulated. Typically the governing authority in a jurisdiction must approve equipment for use in the unlicensed bands. Limits on power and types of modulation are commonly used to ensure that unlicensed equipment "plays nice" with other unlicensed users in the same band. Power limitations

reduce the potential range and achievable data rates for communications, especially in non line of sight deployments. Due to the significant degree to which power is limited in most unlicensed applications, this effect can be very substantial.

Competitive Overview

As discussed in more detail below, a variety of competing technologies are used for delivering broadband access to consumers. As shown in this chart, the number of broadband subscribers has grown rapidly, with cable and DSL technologies being most prevalent.

Exhibit 5: Number of US Broadband Subscribers



Source: Federal Communications Commission

…many cable operators have taken advantage of the substantial bandwidth available on their systems to offer digital services, most notably voice communications and data connectivity to the internet.

Cable

Cable Television service providers, though their Hybrid Fiber Coax networks, provide a very "fat" pipe to end users – typically capable of hundreds of megabits or even more. Traditionally this fat pipe has been used to provide analog video programming. However, during the last few years, many cable operators have taken advantage of the substantial bandwidth available on their systems to offer digital services, most notably voice communications and data connectivity to the internet.

Cable Modems are the means of providing this connectivity, and are produced to a series of evolving standards call DOCSIS. The currently most advanced standard is DOCSIS 3.0, which supports theoretical download rates of 160 megabits per second. However, because cable networks are (for now, at least) unswitched the various users on a node must share this capacity. As a result,

typical data rates are 10 megabits or less – often as little as 1.5 megabits. These data rates are often faster than competing services available through DSL (see below).

Penetration of cable modem services is relatively widespread and is continuing to increase as more cable operators upgrade their plant.

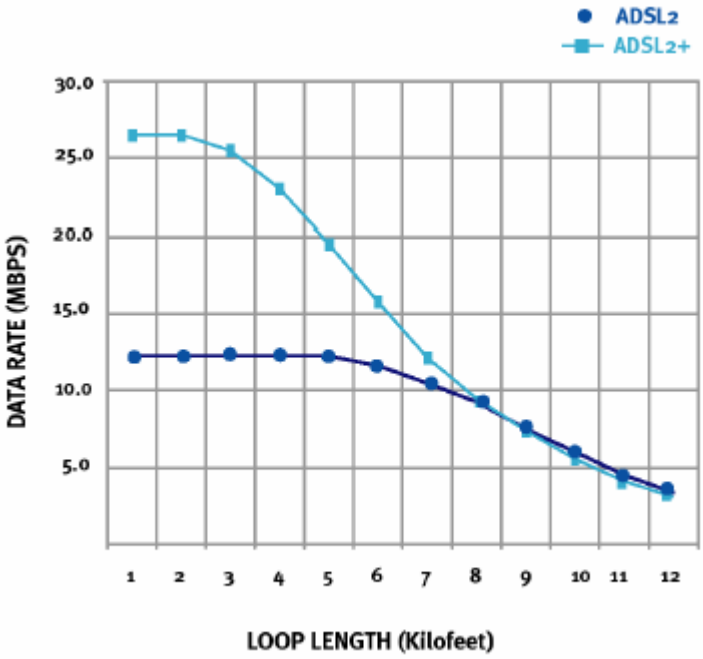
Pricing for cable modem subscribers is typically $40 per month or more, and the service is often bundled with voice and video services (the so called "triple play" of voice, video and data).

DSL

Because DSL is a switched technology, capacity is not shared and each user gets the full use of whatever data rate is available over the line.

Digital Subscriber Line (DSL) is a technology for sending digital data down telephone lines. It is offered by both the telephone companies that own the lines as well as Competitive Local Exchange Carriers (CLECs) that lease access to the lines. Due to the limitations of the twisted copper pair used to carry its signals, the data rates achievable by DSL drop off over distance from the central office. Downstream data rates can be as high as over 25 megabits per second, but typically are more in the range of 3 megabits or less. Because DSL is a switched technology, capacity is not shared and each user gets the full use of whatever data rate is available over the line.

Exhibit 6: ADSL2plus Doubles the Maximum Downstream Data Rate



Source: Cisco

Because of the need for subscribers to be located close to the central office, availability of DSL is not as high as cable modems.

Pricing for DSL service is often significantly cheaper than cable modem service, and is nearly always bundled with voice telephony. More recently, a number of DSL providers have started to offer bundled video services as well.

Data rates of ~10 megabits per second have been achieved in [BPL] test rollouts in the United States…

BPL

Broadband over Power Line (BPL) is an emerging technology that is likely to provide substantial competition to other means of providing broadband access. Data rates of ~10 megabits per second have been achieved in test rollouts in the United States, but widespread deployment has been awaiting more development of the business model to pay for the data distribution infrastructure.

Satellite

Two satellite broadband operators, Hughesnet and Wildblue have a combined subscriber base of ~500,000 subscribers in the U.S., which is currently estimated to be growing at ~25,000 subscriber per month. IPStar also offers satellite broadband service in Asia to a base of over 50,000 subscribers. Data rates for the return (i.e. ground to satellite channel) are significantly slower than competing technologies. Satellite broadband services require the use of a rooftop dish such as the 0.75 meter IPStar dish shown here.

Satellite broadband subscribers in the U.S. are currently estimated to be growing at ~25,000 subscriber per month.

Exhibit 7: A Typical Broadband Satellite Dish

Source: IPstar

Broadband Wireless Ecosystem

Through the efforts of the WiFi Alliance, WiMax Forum, Qualcomm Corporation, Motorola and others, there have been efforts to produce a large, diversified infrastructure base of software, hardware and services for each of the respective competing approaches to implementing broadband wireless. The result has been the emergence of ecosystems for each of these respective technological approaches.

The most mature of these "ecosystems" are WiFi and EV-DO, both of which have wide deployment, and in the case of EV-DO benefit from piggybacking on cellular voice infrastructure already in place. In the case of these mature ecosystems, through consolidation and scale, substantial barriers to entry for new companies are effectively in place, and the nature of competition is largely confined to the incumbent providers. In the case of WiMax, however, there is considerably less structure and more uncertainty regarding the future state of that sub industry. While new entrants continue to proliferate, Near Earth expects a long term consolidation trend to emerge in WiMax that will substantially reduce the number of market participants over time.

Hardware Providers

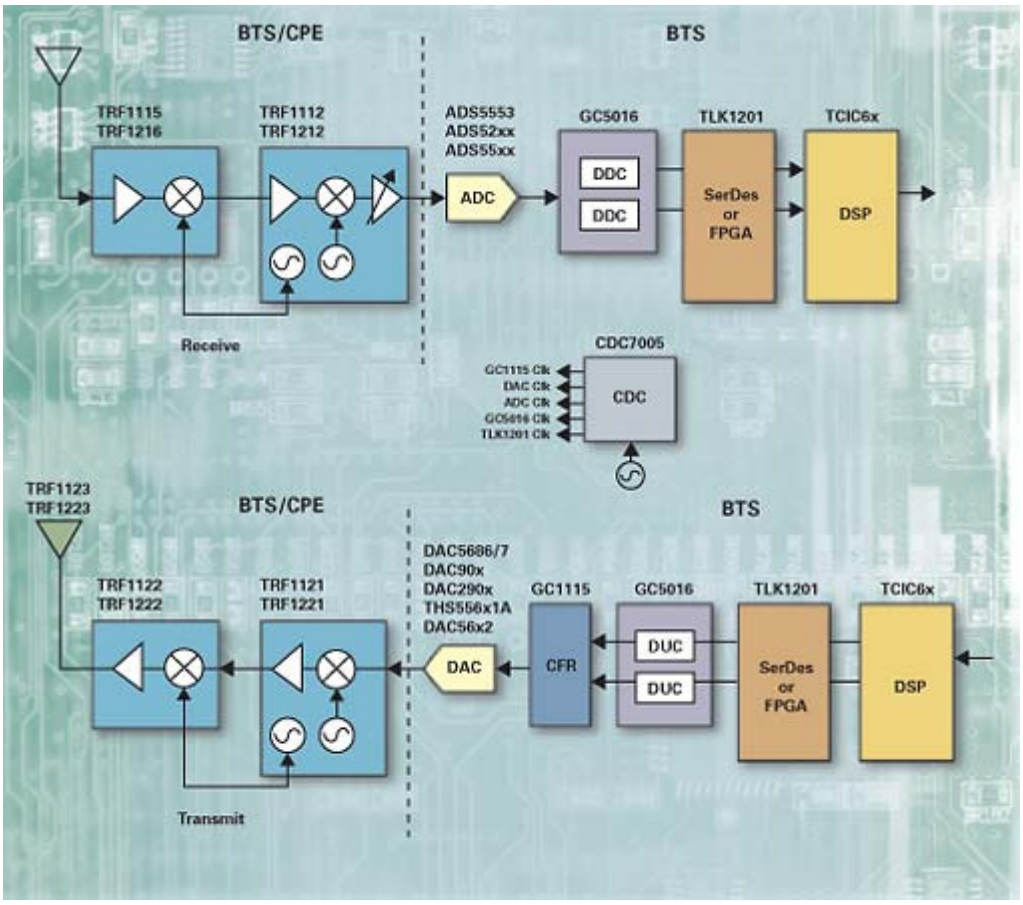
Chipsets

A variety of specialized integrated circuits are required to receive and process the signals used to propagate broadband wireless service. These include:

- RF upconverters
- RF downconverters
- Power amplifiers
- IF transceivers
- Analog to digital converters (ADCs)
- And more…

The use of the various components is shown in the figure below:

Exhibit 8: Components Used to Propagate Broadband Wireless Service



Source: Texas Instruments

Because of the substantial costs for circuit design, these components are provided by a short list of semiconductor manufacturers – with and without their own fab facilities. Because the entire market for wireless broadband equipment is going to contain these chipsets, we expect the overall market to be robust as broadband wireless acceptance grows. The very substantial barriers to entry that the non recurring engineering expenses and technical complexity impose for these companies is likely to keep the overall number of entrants relatively small.

Some of the current market participants include:

TI (NYSE: TI) produces full sets of 802.16 compliant chipsets for the 2.5, 3.5 and 5.8 GHz frequencies. TI is publicly traded on the New York Stock Exchange under the symbol TI.

Telecis is a fabless manufacturer that produces 802.16 “systems on a chip” that incorporate most chipset functionality onto a single chip. These chips are more compact and consume less power than many competing designs and are compatible with a variety of frequencies. Telecis is venture backed by ATA Ventures and Samsung Ventures, among other major backers. The firm has raise $18.7mm in funding to date, most recently a $10mm round in June 2006. Telecis is based in Santa Clara, California.

Intel (Nasdaq: INTC) has been active in broadband wireless through two technology initiatives. First, Intel has developed and pushed the adoption of its Centrino technology for WiFi receivers for laptop computers. Second, Intel has also been the largest backer of WiMax, at least from a dollar perspective. Intel, through its Intel Capital venture arm, most recently invested $600 million in the ClearWire broadband wireless service operator, clearly with the intent of assuring demand for its CPE and base station chipsets.

Intel has also been a big investor of companies that populate the downstream portion of the wireless broadband infrastructure – including most notably the following:

- Aeroscout (WiFi based motion capture and asset tracking)
- Navini (broadband wireless antenna technology)
- Skyhook Wireless (WiFi based geolocation)
- Tropos Networks (WiFi based mesh networks)

Intel itself has also invested substantially in developing its own WiMax chipmaking infrastructure and appears to be attempting to repeat its Centrino strategy in the WiMax space. While the company does not release exact figures, we believe that its revenues from the Centrino product line exceed $5 billion per year.

Metalink (Nasdaq: MTLK) is an Israel based fabless semiconductor manufacturer that produces chips for 802.11n and VDSL applications. They are public and trade on the Nasdaq with ticker MTLK. Revenues for the trailing twelve month period were $15.2mm, and the company trades with a market capitalization of $108mm.

Broadcom (Nasdaq: BRCM) is a fabless semiconductor manufacturer based in Irvine, California. Broadcom's Airforce line of 802.11a/b/g/n compatible chips are used for WiFi cards in products by Apple, Belkin, Buffalo, Dell, eMachines, Gateway, HP, Linksys/Cisco, and Motorola. Broadcom is also a supplier of chipsets for UMTS. Broadcom's mobile and wireless sales, which include the wireless broadband component, are approximately $1 billion per year.

Atheros (Nasdaq: ATHR) produces 802.11a/b/g/n chipsets and single chip solutions for OEM providers. The company is particularly focused on long range applications of WiFi. Atheros recently (October 2006) acquired gigabit Ethernet networking firm Attansic with the intent of incorporating the respective firms' capabilities into 802.11n routers with speeds north of 100 megabits per second. Atheros is based in Santa Clara, California. Atheros has annual sales of $300mm.

Qualcomm (Nasdaq: QCOM) is the major licensor of CDMA technology and provider of chipsets for wireless infrastructure. This includes voice as well as the EV-DO data services. The firm is also leading the development and deployment of the MediaFLO data broadcasting system, which is intended for video broadcasting to handsets. Qualcomm is headquartered in San Diego, California. Qualcomm has sales of $7.1 billion.

IPWireless is a provider of chipsets for UTMS. The company has raised over $200mm in venture capital from investors including Doll Capital, Gabriel Ventures, J.F. Shea, Northwood Ventures and others. IPWireless is based in San Bruno, California.

Sequans provides WiMax compliant systems on a chip with bundled software. The company's products support both the mobile and fixed WiMax standards. Sequans is venture capital backed by Add Partners, CapDecisif, Vision Capital and others. The company's chipsets are used by Soma Networks, Aperto, WiNetworks and others. The company recently (June 2006) closed on a $24mm funding round. Sequans is based in Paris, France.

Fujitsu markets a full range of fixed and mobile WiMax compliant systems on a chip for OEM manufacturers. Fujitsu is based in Tokyo, Japan.

Base Stations/Subassemblies/CPE

The definition of what constitutes a "base station" in broadband wireless is somewhat arbitrary – in the case of this white paper, we consider the base station the location where the air link is converted to Ethernet and typically backhauled to the internet infrastructure. In some cases, this backhaul may also use a wireless link, but this is usually transparent from the base station point of view. We provide below a list of some of the market participants in each category of base station. These lists are by no means comprehensive.

WiFi

WiFi "base stations" are typically just wireless routers that employ chipsets or systems on a chip

WiFi "base stations" are typically just wireless routers that employ chipsets or systems on a chip from the vendors identified above. Since broadband wireless as used in this white paper is focused on providing last mile access to consumers and business, we are interested in manufacturers that address this segment, however. Due to mass production and learning curve effects, the cost for this equipment has fallen significantly and continues to erode over time.

Some of the significant scaled WiFi system vendors include the following:

In addition to its better known indoor wireless LAN offerings, Cisco (Nasdaq:CSCO) builds WiFi mesh networks (branded Aironet) and focuses its marketing efforts on the oil and gas industry, municipal and public safety markets. Cisco does not break out its broadband wireless revenues separately.

Tropos specializes in WiFi mesh networks, and is the largest player in that sector of the market with over 500 deployments worldworldwide. Tropos has a strong relationship with service provider Earthlink Networks. Tropos is privately held and is backed by Intel Capital, Benchmark Capital and Integral Capital Partners, among others.

Nortel (Toronto:NT) produces WiFi and WiMax base stations, access equipment and software. The company does not disclose its sales for this sector, though we believe they are significant.

Packethop specializes in deployable mesh networks that use licensed (4.9 GHz public safety band) and unlicensed spectrum for disaster recovery, events and public safety applications. The networks rely on enhanced transmission range to reduce the number of nodes required for quick deployment. Packethop is privately held and has raised over $25mm in venture financing from investors including U.S. Venture Partners, Mayfield Venture Capital, Comventures and others.

SkyPilot manufactures WiFi mesh network components for municipal and other mesh deployments. Its products feature advanced antenna designs that increase capacity. The company has over 300 customers in 50 countries that have deployed over 25000 units. SkyPilot is privately held and has raised over $68mm in venture financing from investors including August Capital, Mobius Venture Capital and others.

Proxim is a wholly owned subsidiary of publicly traded Terabeam (Nasdaq: TRBM). The company produces both WiFi and WiMax equipment for both last mile and backhaul applications. Proxim also markets very high capacity wireless point to point backhaul equipment that does not meet either standard. Revenues for the trailing twelve month period were $84.2mm, and the company trades with a market capitalization of $44mm.

XIRRUS

Xirrus provides WiFi base stations with enhanced range as well as software and other security and network management components. Xirrus is privately held and venture backed by U.S. Venture Capital and August Capital. The company raised an undisclosed amount of funding in early 2006.

WiMax

WiMax equipment recently entered production (the WiMax forum certified the first equipment in 2006). WiMax certification consists of a process where equipment is verified to be "plug compatible". Some of the manufacturers below make equipment that is similar in standards to WiMax, but that falls short of true plug compatibility – this equipment is often referred to as "pre WiMax" or "proto WiMax".

Over time, we expect a consolidation trend to emerge and the number of [WiMax] equipment providers to shrink significantly.

Since broadband wireless as used in this white paper is focused on providing last mile access to consumers and business, we are interested in manufacturers that address this segment, however. Due to mass production and learning curve effects, the cost for this equipment has fallen significantly and continues to erode over time. In time, we expect learning curve effects in the market for WiMax equipment to parallel those in WiFi equipment.

Over time, we expect a consolidation trend to emerge and the number of equipment providers to shrink significantly.

Some of the more noteworthy WiMax equipment providers include the following:

Airspan

Airspan (Nasdaq:AIRN) is a manufacturer of WiMax certified base stations and CPE for both the fixed and mobile WiMax standards. Its products are available for both the licensed and unlicensed bands from 2.3-5.8 GHz, and include both indoor (NLOS) and outdoor install versions. The company also has broadband wireless equipment using the unlicensed WiFi standard and using its own proprietary standards. In addition to its products the company also provides consulting and implementation support services and VOIP software to its customers. Airspan has over 400 customers in more than 100 countries, and has annual sales of ~$125 million.

alvarion

Alvarion (Nasdaq: ALVR) is the largest WiMax vendor in the world (but not the largest broadband wireless vendor – that's Motorola). The company boasts of over 300 network deployments in over 100 countries. Alvarion has a very broad line of equipment featuring a variety of frequencies, LOS and NLOS installations

and licensed and unlicensed equipment. Alvarion has about $180 million in annual sales.

Aperto Networks manufactures WiMax certified base stations and CPE for fixed broadband wireless deployments. These include both the outdoor LOS/NLOS Packetwave (pre WiMax) and PacketMax lines of outdoor and self install WiMax certified equipment, which also include integrated VOIP capability. Aperto is privately held, was founded in 1999 and has raised over $120 million in venture capital funding to date.

Motorola (NYSE: MOT) is perhaps the largest manufacturer of broadband wireless equipment in the world. Their Canopy line of broadband wirelesss access equipment supports frequencies from 2.4-5.7 GHz with a proprietary standard. Motorola's full portfolio offering includes software and systems for outdoor NLOS and LOS deployments, as well as WiMax deployments. CPE prices begin at as low as $200 suggested retail. Motorola's extensive experience in the mobile voice and data communications industry strongly suggests that they will be a factor in mobile WiMax rollouts. Motorola has invested in ClearWire and is one of three major vendors (along with Nokia and Samsung) for Sprint's multibillion dollar WiMax deployment.

Navini offers a variety of pre WiMax compliant products focused particularly on the 802.11e mobile standard and NLOS installations. There are over 70 Navini deployments worldwide. The company manufactures base stations, CPE and support equipment for the licensed 2.3, 2.5 and 3.5 GHz bands as well as unlicensed equipment for the 2.4 GHz band. The company also focuses on MIMO and advanced beamforming antenna technologies to increase network capacity and throughput. Navini has its development center in India, and is privately held and backed by Austin Ventures, Intel Capital, Sequoia Venture Capital and others. Their most recent investment was $17.5mm, from Intel Capital in June 2006.

Proxim Wireless – In addition to its WiFi and millimeter wave offerings (detailed above) Proxim also has a full line of WiMax compliant broadband wireless offerings. As noted previously, Proxim is a division of publicly traded Terabeam.

Redline Communications (AIM: REDL) manufactures WiMax compliant equipment for both the fixed and mobile standards. The company claims its equipment is used in over 100 installations in over 40 countries. Redline's 2006 sales were $35mm. The company went public in December 2006, raising $27mm in gross proceeds.

Soma Networks specializes in indoor, user-installed, NLOS deployments using WiMax certified equipment for both the fixed and mobile standards. The company's products include integrated VOIP and are designed to use the licensed 700 MHz, and 2-3-3.5 GHz bands. Soma is privately held, venture funded and has garnered more than $175 million in private equity since 1999.

Trango manufactures licensed and unlicensed base stations and CPE for the 2.4, 4.9, and 5.8 MHz bands. They also provide point to point microwave backhaul equipment for the 18 MHz licensed band as well. Their product line includes point to point WiMax solutions for backhaul, point to multipoint fixed wireless solutions for enterprises and WISPs and wireless mesh network equipment. Their products use a closed, proprietary standard. The company boasts of over 300,000 radios in its installed base. Trango was founded in 1996 and is privately held and has no institutional investors.

Israel based WiNetworks offers conventional CPE and base station pre WiMax products for a variety of bands, including 1.5, 2.4, 2.5 and 3.5 GHz. They also offer a variety of media gateways for triple play services and in-home networking. The company's most noteworthy technology is the development of CPE units that integrate with DBS roof mounted antennas and share the electrical and RF connectivity the DBS antenna uses. They also are developing an innovative mesh technology that would allow the customer mounted roof antennas to comprise a network. WiNetworks has no significant deployments in place as yet. WiNetworks is privately held and venture backed by Rho Capital, Columbia Capital, Evergreen Venture Partners and The Cedar Fund.

EV-DO handsets are rapidly being introduced by cellular/PCS equipment providers.

EV-DO

EV-DO handsets are rapidly being introduced by cellular/PCS equipment providers. As of November 2006, there were 31 EV-DO capable handsets available in the United States from a variety of providers, including LG, Motorola, Samsung, Nokia and others. Typical pricing was ~$140 for low end handsets and $250 or more for high end handsets. Wireless cards for use with laptop computers are available from Pantech Wireless, Sierra Wireless, Novatel and others.

EV-DO base station equipment is also available from a variety of vendors, including Airvana, Lucent, Samsung, Nortel, Motorola and others.

UMTS

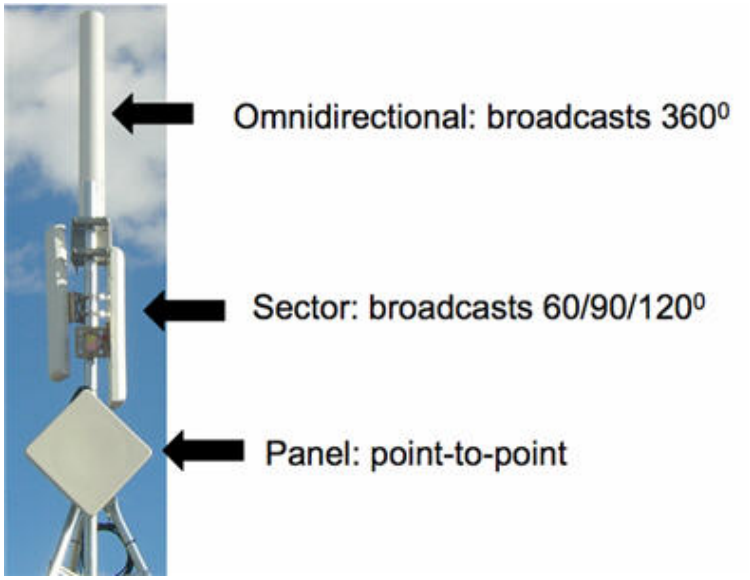
UMTS handsets are also being introduced by cellular and PCS equipment providers, but due to its heritage derived from the GSM standard, the cast of characters is different.

Antennas

Just as there are different radio frequencies for various modes of wireless broadband access, so there are a variety of antennas available. However, regardless of frequency, all antennas can be divided into categories that reflect how the radio waves are directed as they are emitted from the antenna.

The figure below illustrates the three main types of antennas used in WiMAX deployments – while they look different, the same distinctions apply for antennas for WiFi, EV-DO, UMTS and other technologies. From top to bottom are an omnidirectional, sector and panel antenna; each has a specific function.

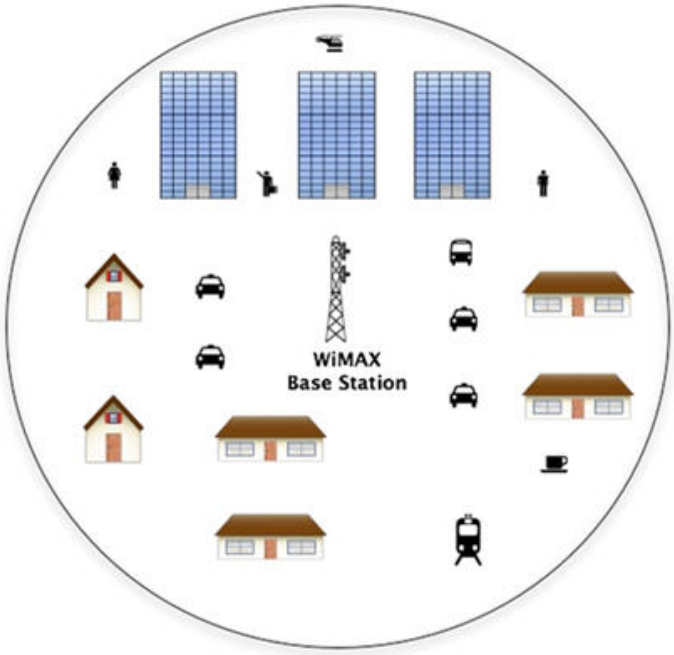
Exhibit 9: From Top to Bottom, an Omni directional, sector and panel antenna



Source: WiMax.com

Omni directional antennas

Exhibit 10: Omni directional antennas broadcast in all directions

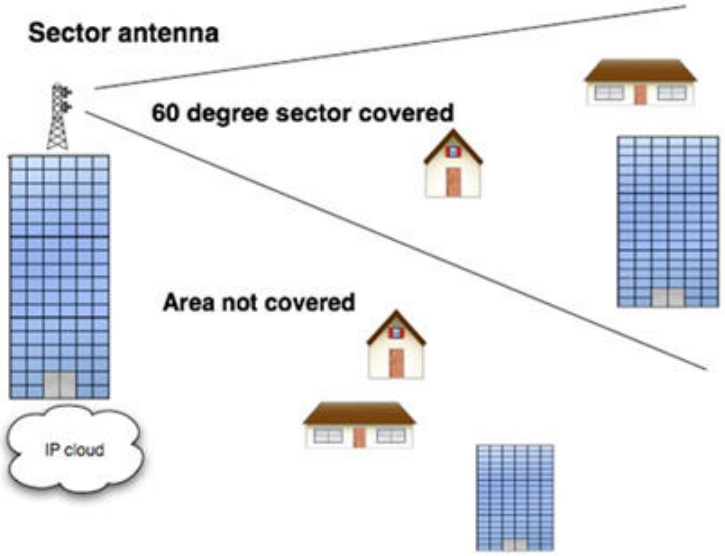


Source: WiMax.com

Omni directional antennas are used in base stations for point-to-multipoint configurations. The main drawback to an omnidirectional antenna is that its energy is greatly diffused by broadcasting in all directions. This limits its range and ultimately its signal strength. Omni directional antennas are good for situations where there are a lot of subscribers located very close to the base station. An example of omnidirectional application is a WiFi hotspot where the range is less than 100 meters and subscribers are concentrated in a small area. Likewise, mobile and nomadic receivers such as laptop users or automobiles generally use omnidirectional antennas since it is impractical to aim the end user's equipment frequently.

Sector Antennas

Exhibit 11: Sector antennas concentrate on a particular area.



Source:WiMax.com

A sector antenna, by focusing the beam in a more focused area, offers greater range and throughput with less energy. Many operators use multiple sector antennas to cover a 360-degree service area rather than use an omni directional antenna due to the superior performance of sector antennas over an omni directional antenna. In addition to greater range, this configuration can allow the simultaneous reuse of particular frequencies by a single base station, increasing its data capacity.

Panel Antennas

Exhibit 12: Panel antennas are most often used for point-to-point applications

Source: WiMax.com

Panel antennas are usually a flat panel of about one foot square. They can also be a configuration where potentially the WiMAX radio is contained in the square antenna enclosure. Such configurations are powered via the Ethernet cable that connects the radio/antenna combination to the wider network. That power source is known as Power over Ethernet (PoE). This streamlines deployments as there is no need to house the radio in a separate, weatherproof enclosure if outdoors or in a wiring closet if indoors. This configuration can also be very handy for relays or backhaul of other wireless traffic.

Handheld Portable Devices

Broadband wireless networks will only succeed on a large scale if consumers have access to portable devices that can truly capture the full benefits of such networks' mobility. The reality is that few people would subscribe to such a network if the only devices that worked were laptops. As such, we expect mobile devices, most notably phones and PDA's, to come to market in the US with the ability to access multiple types of networks. The obvious example is Apple's iPhone which can access WiFi networks and also AT&T's cellular network. Much to current cell phone companies' dismay, phones that will be able to access wireless broadband connections will soon have the ability to bypass the cellular network altogether when making calls by utilizing the wireless broadband connection and VoIP technology.

The broadband wireless industry also relies on a variety of support providers that provide specialized services.

Support Providers

The broadband wireless industry also relies on a variety of support providers that provide specialized services. Many of these providers also serve competing or otherwise related industries as well. Examples include tower leasing companies, operations support software and billing support software vendors and systems integrators that assist in system design and construction.

Service Providers

The service provider component of the broadband wireless industry is really bifurcated into two divisions – on the one hand we have the very well funded firms that have scale – Sprint, ClearWire and Earthlink, and on the other hand there's everyone else. Other ways of slicing up the service provider pie include by technology – where ClearWire and Xanadoo, and Towerstream are pure WiMax plays while Covad and Earthlink are wired ISPs with WiMax components, Metrofi, and Mobilepro are mesh WiFi plays.

In addition to the publicly held and venture backed companies identified below, there are a large number of smaller Wireless Internet Service Providers (WISPs) that are privately held.

Sprint

Sprint (NYSE:S) is the granddaddy of WiMax firms, with the most experience, financial resources, greatest amount of licensed spectrum and best recognized brand of any of these firms. The company has announced that they intend to spend over $2.5 billion in 2007 and 2008, with more thereafter, to deploy the mobile version of WiMax in geographic regions that cover over 100 million people. The company intends to extend its coverage thereafter; their 2.5 GHz license holdings cover 85% of the households in the top 100 markets. Initial markets are Washington D.C. and Chicago, with mobile service in the 1-3 megabit range planned for late 2007. The company may also offer fixed and nomadic service models, which more closely resemble those at its competitor Clearwire.

Sprint obviously benefits from marketing and operational synergies between their substantial existing voice and data operation, which is based on EV-DO technology and the WiMax data service it is introducing. Do to the substantial spectral efficiency benefits of WiMax, we expect Sprint to preferentially direct "power users" with substantial bandwidth requirements to WiMax, thus reserving its more valuable EV-DO spectrum for voice and light data users, with obvious cost benefits. We also expect that the company will bundle its voice and data offerings to increase customer stickiness. Sprint has indicated that initial pricing will be $55 per month for unlimited service.

clearwire
a simpler way to internet™

Clearwire (NASDAQ: CLWR) is the largest operational WiMax firm, with over 250,000 fixed broadband subscribers, about 2.5% of the 10 million households in its service area. Most of these subscribers are in the United States, but about 20,000 of them are in Europe.

ClearWire's fixed broadband service is offered at prices as summarized below:

Exhibit 13: Clearwire's Fixed Service Pricing

ClearValue	Up to 768 Kbps	Up to 256 Kbps	$ 24.99 - $29.99	3 email addresses
ClearPremium	Up to 1.5 Mbps	Up to 256 Kbps	$ 34.99 - $37.99	5 email addresses, 10 MB web hosting account
ClearBusiness	Up to 1.5 Mbps	Up to 256 Kbps	$ 49.99	8 email addresses, 25 MB web account, 1 static IP address

Source: Clearwire

Many of these subscribers choose to bundle a VOIP service to gain low cost access to fixed voice communications as well. This facility based VOIP service is priced at $34.95 per month for unlimited service.

The company relies on its substantial 2.5 MHz spectrum holdings in the United States to provide service, and additional spectrum holdings in Europe. These spectrum holdings consist of 12 billion MHz-POPs of owned (25%) and leased (75%) spectrum in the United States in the 2.5 GHz band. The company also controls an additional 8.5 MHz-POPs of spectrum in Europe, principally in the 3.5 GHz band.

EarthLink

Earthlink (NASDAQ: ELNK) is principally a wired internet service provider. The company provides both narrowband (i.e. dialup) as well as broadband internet access to 4.2 million subscribers. In addition to its wired offerings, Earthlink also has been at the forefront of municipal WiFi, where it has partnered with the cities of Philadelphia, Milpitas, Corpus Christi, New Orleans and Anaheim to offer broadband service. While 3 additional cities are in the planning stages, the company has indicated in public statements that it intends to monitor the financial performance of its current and committed deployments before entering into additional commitments. Typical service plans are in the $20/month price range.

Xanadoo
wireless high-speed internet

Xanadoo (Pink Sheets: XAND) operates a fixed and nomadic wireless broadband service using unlicensed spectrum and licensed 2.5 GHz spectrum covering approximately 8 million people in Texas and Oklahoma. The company has approximately 6,000 subscribers. Plans offer speeds from 128kbps to 1.5mbps with prices starting at $14.95 per month ranging to $39.95 per month and are divided between both business and residential users.

COVAD

Covad(Amex: DVW) is principally a wired ISP but recently diversified into wireless broadband through the acquisition of Nextweb in February 2006. The company has approximately 4,000 subscribers to its service, which is largely a T1 replacement service with speeds in the multi megabit range. The company relies on pre WiMax technology using licensed and unlicensed spectrum. Plans begin at $299 per month for 1.5mbps and include service level guarantees. Data rates of as much as 100 mbps are offered. Covad uses 5.8 MHz unlicensed line of sight technology for last mile connectivity and licensed spectrum for backhaul. The company is currently offering service in parts of San Francisco, Las Vegas, Los Angeles and Chicago.

MetroFi

Metrofi is a municipal WiFi operator with operations in nine cities, including seven in California. Their largest operations, in Portland, boasts over 11,000 users. The company uses a hybrid advertising and fee supported business model, with ad free versions starting at $19.95 per month. Data rates of up to 1 mbps are offered. MetroFi is venture backed by August Capital, Sevin Rosen and Western Technology, and has raised $15mm to date, most recently in October 2006.

MobilePro

Through its Kite Networks subsidiary, Mobilepro (OTCBB: MOBL) offers fixed wireless and municipal mesh WiFi network broadband service to business and residential customers. The company has over 20,000 subscribers in approximately 25 jurisdictions. The company uses a wholesaler business model in most markets. The company has hired BB&T to help it evaluate strategic opportunities for its Kite Networks subsidiary.

towerstream

Towerstream (Nasdaq: TWER) is a provider of business T1 substitution services using pre WiMax technology using line of sight installations and unlicensed spectrum. Packages start at $525/month for T1 connectivity, and the company offers services with data rates up to 1 gigabit. The company's geographic coverage includes New York, Los Angeles, Chicago, Boston, San Francisco and parts of Rhode Island. Towerstream serves business and commercial customers exclusively. The company raised $40 million in June 2007 through a secondary offering.

Through its Ricochet Networks subsidiary, Terabeam (Nasdaq: TRBM) provides wireless internet service to 6,000 subscribers in San Diego and Denver. The technology for this deployment is proprietary, but similar to WiFi mesh, and offers speeds of 128 kbps. Ricochet has announced its intention to migrate to WiFi mesh (to be supplied by Terabeam's Proxim subsidiary) in the future, although its parent Terabeam has also announced that it is evaluating strategic alternatives for Ricochet, which casts some doubt about the aforementioned upgrade. Prices start at $24.99 per month for service.

Financial Landscape

Industry Economics

Demand

…demand function for the broadband wireless access industry is being driven by a combination of increased internet usage and the increasing use of the internet to deliver rich media…

The overall demand function for the broadband wireless access industry is being driven by a combination of internal and external factors. Externally, as internet usage by both businesses and residential users continues to grow, it is increasing the demand for access in progressively more remote areas, where wired options (i.e. dialup, DSL and cable modems) are limited or entirely unavailable. Likewise, the increasing use of the internet to deliver rich media, video in particular, is also driving increased demand for faster connections (i.e. broadband).

In addition, we expect that information centric modern police work and increased use of the internet and the infrastructure for electronic surveillance by both federal and local authorities will drive the construction of closed broadband wireless networks using public safety spectrum and unlicensed spectrum.

Specific evidence of these trends can be found by the increasing penetration of broadband as a fraction of the overall market (in 2006, it passed the 50% penetration level), and especially the strong market acceptance for satellite broadband, despite its higher price points and relatively slow uplink capabilities.

Supply and Competition

To answer this demand, service providers have responded by increasing capacity and rolling out service in new areas. For example, WildBlue launched their service from their second satellite in 2007, WiFi mesh networks were lit up in Philadelphia, Portland and many other cities and ClearWire increased its service area and continues to do so. Given the relatively limited coverage of broadband wireless as compared to DSL, cable and satellite based solutions, competition as yet remains muted.

…we expect that some degree of direct competition between broadband wireless providers will emerge

Over time, however, we expect that some degree of direct competition between broadband wireless providers will emerge. We are already seeing some degree of this in unlicensed fixed wireless vendors, such as Towerstream and Covad, which offer competing T1 replacement services in Los Angeles, for example. Similarly, as ClearWire and Sprint roll out more of their licensed WiMax networks, and EV-DO and UMTS become more commonly available, the competitive field is likely to heat up (though, we note that ClearWire and Sprint themselves have decided to cooperate rather than directly compete).

We expect that this competition will lead providers to attempt to differentiate along a number of fronts, driving business models such as these:

- Low cost double play providers – this will consist of providers relying largely on low cost plug compatible WiMax equipment and unlicensed spectrum to provide relatively high rate service bundled with VOIP to fixed users. Using their low cost model, we expect these operators to go after higher cost satellite, cable and DSL providers.
- Partnered triple play providers – Clearwire, through its partnership with satellite video companies like Echostar and DirecTv, illustrates this model,

though we expect its adoption to be extended to other video providers as well. This allows an offering comparable to the popular triple play currently offered by cable, and increasingly telco providers.

- Level of Service differentiated providers – these companies will offer higher data rates and guaranteed level of service, principally to business customers.
- Public/private partnerships – We expect that this model, which often relies upon some degree of public funding (either directly, for capital expenditures, or by the government agreeing to serve as an anchor tenant), will continue to proliferate using both mesh WiFi and WiMax deployments.

On the equipment side, we expect competition will continue to be fierce on the WiFi side, and become progressively more so on the WiMax side. Here, scale will prove to be a strong success factor, and as a result, we expect a strong motivation on the part of manufacturers to consolidate.

Recent M&A Transactions

Exhibit 14: Recent Transactions

Acquirer	Target	Business	Price ($million)	Date
Towerstream	Speakeasy (wireless assets)	Business WISP		
Nextwave	GO Networks	WiFi Technology	$13.3 to $25.7	
Aetheros	ZyDAS	WiFi chipsets	$23	
Cisco	Linksys	WiFi equipment	$500	3/2003
Siemens	Chantry Networks	WiFi equipment and software	Not disclosed	12/2004
Cisco	Airespace	WiFi equipment	$450	1/2005
Wireless Age	mmwave Technologies	RF Components	Not disclosed	2/2005
Terabeam	Proxim	Mesh WiFi and WiMax	$28	6/2005
Covad	Nextweb	Business WISP	$24.7	10/2005
Alcatel	Nortel UMTS business	UMTS hardware	$320	9/2006
Technitrol	Radiall/Larsen Antenna Technologies	WiFi and WiMax antennas	Not disclosed	10/2006
Qualcomm	Airgo	WiFi chipsets	Not disclosed	12/2006
Nextwave	IPWireless	UMTS Technology	$100 to $235	4/2007
WPCS International	Major Electric	System Integrator	$4 to $7	6/2007

Source: Near Earth Analysis Research

Future Industry Prospects

With strong and growing demand for fast internet connectivity, especially on a mobile basis, we expect continued growth of broadband wireless in the aggregate. The "winning" technologies (and thus, industry participants) are likely to vary depending on application, portability, competition and cost of service. We therefore expect that certain technologies and their proponents will develop their own niches of strength, with blurry boundaries.

Some of the stronger niches and industry trends that we expect to develop include the following:

- **Satellite broadband and traditional wireless broadband service operators and equipment providers are likely to converge.** We think that it is natural for satellite broadband service providers to seek alliances with terrestrial wireless broadband service providers. Terrestrial broadband wireless consumer premises equipment is significantly cheaper and with spectrum reuse through cell that are far smaller than satellite spot beams, more cost effective on a per bit basis as well. As such, we believe that satellite broadband is not going to be able to compete with terrestrial broadband where it is available. However, for terrestrial broadband to be cost effective, a certain density of users is required. This leads to the obvious approach of selling satellite broadband into a broad geographic region, and then migrating the users to terrestrial broadband when and where the critical density is reached to justify the construction of terrestrial infrastructure. This greatly lowers the risk of the terrestrial rollout while increasing the lifetime customer value. Similarly, on the equipment side, vendors are going to be in a stronger position to market to these hybrid firms if they have a unified offering, and will benefit from the scale effects of having multiple synergistic product lines.

- **WiMax Forum plug compatibility is likely to rapidly drive equipment prices lower, leading to furious consolidation amongst equipment providers.** Just as we have seen in the WiFi industry, price competition in the WiMax equipment areas is likely to be intense. Because of this, only equipment providers with significant scale advantages are likely to be able to survive, and we believe that many will choose to gain scale through M&A activity. We believe that the major wireless infrastructure companies (i.e. Ericsson, Motorola, etc.) will also apply considerable pressure.

- **In more rural areas, unlicensed service operators are likely to gain significant economic advantage.** Because unlicensed equipment uses lower power levels than licensed equipment, generally speaking ranges are shorter and more equipment must be deployed than in licensed systems. However, due to the plug compatibility and rapid price erosion for equipment, we believe that by avoiding the cost of buying spectrum and "throwing more equipment at the problem" these providers could gain a cost advantage over their licensed competitors. We also note that the unlicensed bands include very wide swaths of spectrum (up to 125 MHz) that can support data rates and throughput significantly in excess of those for licensed spectrum (which is generally available in 60 MHz or smaller chunks).

- **Prices for WiMax spectrum and 3G spectrum are likely to trend towards converging.** With emergence of the mobile WiMax standard, the use of

software to provide QOS, especially over licensed spectrum and cheap VOIP infrastructure, we believe that the functionality of WiMax spectrum will approach that of 3G spectrum, and that as a result the prices for the respective spectrum types will begin to converge. We believe this will result in significant appreciation of WiMax spectrum assets.

- **Broadband wireless operators are likely to form alliances with video and conventional 3G wireless operators to form strong bundled offerings.** This represents a continuation of the trend already demonstrated by the alliance between ClearWire and the DBS firms, and the alliance between the satellite broadband provider WildBlue and rural telcos and video providers. A significant portion of the market likes bundles, and the market will give it to them.

- **T1 substitution operators are likely to flourish on the dying corpse of wired T1 services for some time, but will eventually start to bump into each other.** The wired T1 service ILECs are likely to maintain high prices until some tipping point is reached that forces them to respond to market share erosion from wireless T1 substitution operators. While this will present a substantial opportunity for the wireless operators, the low barriers to entry to this market will eventually result in substantial competition and price erosion for all participants. This price erosion will be exacerbated when the wired participants (who have very low marginal operating costs and who are using fully depreciated equipment in many cases) are forced to respond to wireless entrants.